PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2001-272555
(43)Date of publication of application : 05.10.2001

(51)Int.Cl. G02B 6/12

(21)Application number : 2000-084869
(22)Date of filing : 24.03.2000

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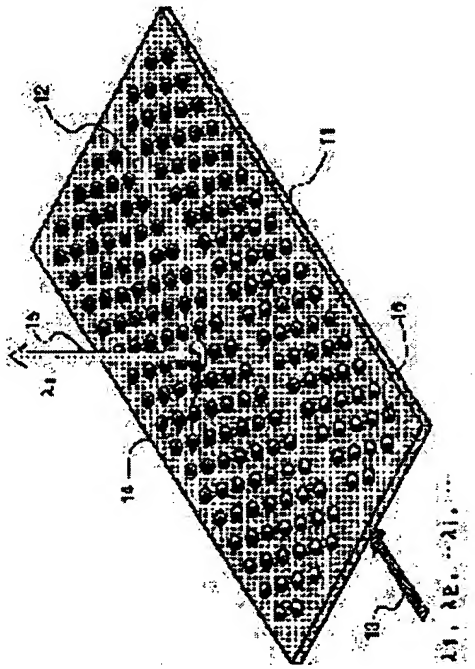
(54) TWO-DIMENSIONAL PHOTONIC CRYSTAL WAVEGUIDE AND WAVELENGTH BRANCHING DEVICE

(57)Abstract:

PROBLEM TO BE SOLVED: To provide an effective form for forming opto-electromagnetic wave waveguides and an opto-electromagnetic wove multiplexer/demultiplexer for introducing or inputting the opto-electromagnetic waves propagating in two-dimensional photonic crystal waveguides to a plane perpendicular direction.



SOLUTION: The two-dimensional photonic crystal waveguide has the photonic crystal waveguides which have a two-dimensional photonic crystal structure formed with a refractive index distribution by periodically arraying materials having the refractive index lower than the refractive index of a slab 11 formed of a material having the refractive index higher than the refractive index of air on the slab material and are formed with wire-shaped defects 12 in the periodic array of the photonic crystals and in which the wire-shaped defects 12 function as the waveguides. The two-dimensional photonic crystal waveguide has at least one dotty defects 4 which disturb the periodic array of the photonic crystals adjacently to the photonic crystal waveguides. The dotty defects 14 function as opto-electromagnetic wave taking-out/ introducing port for capturing and radiating the opto-electromagnetic waves of specific wavelengths among the opto-electromagnetic waves

propagating in the waveguides or capturing the opto-electromagnetic waves of the specific wavelengths from the outside and introducing the same into the waveguides.

LEGAL STATUS

[Date of request for examination]	12.09.2002
[Date of sending the examiner's decision of rejection]	15.06.2004
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]	
[Date of final disposal for application]	
[Patent number]	
[Date of registration]	
[Number of appeal against examiner's decision of rejection]	2004-14940
[Date of requesting appeal against examiner's decision of rejection]	16.07.2004
[Date of extinction of right]	

* NOTICES *

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CLAIMS

[Claim(s)]
[Claim 1] It has the two-dimensional photograph nick crystal structure which arranged periodically the matter with a refractive index lower than this slab ingredient in the slab currently formed from the ingredient with a refractive index higher than air, and formed refractive-index distribution in it. The linear defect is formed in the periodic array of said photograph nick crystal, and this line defect has the photograph nick crystal waveguide which functions as waveguide, and adjoins said photograph nick crystal waveguide. In the light and the electromagnetic wave on which it has at least one punctiform defect which disturbs the periodic array of said photograph nick crystal, and this punctiform defect spreads the inside of waveguide Two-dimensional photograph nick crystal waveguide which functions as the light and the electromagnetic wave ejection / an inlet which captures the light and the electromagnetic wave of specific wavelength, and emits this, or captures the light and the electromagnetic wave of the specific wavelength from the outside, and is introduced in said waveguide.
[Claim 2] Said light and electromagnetic wave ejection / inlet are the two-dimensional photograph nick crystal waveguide of claim 1 which emits / introduces the light and the electromagnetic wave of the direction which intersects perpendicularly with a slab side.
[Claim 3] Said punctiform defect is the two-dimensional photograph nick crystal waveguide of claim 1 from which the wavelength of the light and the electromagnetic wave emitted / introduced with the configuration differs.
[Claim 4] One two-dimensional photograph nick crystal waveguide of claims 1-3 with which a low refractive-index ingredient is filled up into the hole of the shape of a cylinder which the array of said low refractive-index matter formed in slab.
[Claim 5] One two-dimensional photograph nick crystal waveguide of claims 1-4 whose arrays of said low refractive-index matter are triangular lattices.
[Claim 6] Said punctiform defect is one two-dimensional photograph nick crystal waveguide of claims 1-5 which have the configuration of vertical asymmetry to a slab side.
[Claim 7] One two-dimensional photograph nick crystal waveguide of claims 1-6 whose refractive indexes of said slab ingredient are 2.0 or more.
[Claim 8] Said slab ingredient is the two-dimensional photograph nick crystal waveguide of whether it is an inorganic material containing any one sort of In, Ga, aluminum, Sb, As, germanium, Si, P, N, and the O, or two sorts or more, and claim 7 which is an organic material.
[Claim 9] The matter with said low refractive index is one two-dimensional photograph nick crystal waveguide of claims 1-8 which are air [claim 10]. The photograph nick crystal wavelength splitter which has the two-dimensional photograph nick crystal waveguide of claims 1-9.
[Claim 11] The photograph nick crystal wavelength splitter of claim 10 with which the frequencies which have two or more punctiform defects, and this punctiform defect emits / captures differ, respectively.
[Claim 12] The photograph nick crystal wavelength splitter of claims 10 or 11 with which the optical fiber is arranged near the punctiform defect.
[Claim 13] The photograph nick crystal wavelength splitter of claims 10 or 11 with which the semiconductor device which has a photo-electric-conversion function is arranged near [said] the punctiform defect.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the waveguide which has the light and the electromagnetic wave ejection / inlet formed by installation of a line defect and a point defect, and a wavelength splitter about the photograph nick crystal used as a minute optical circuit element, especially the two-dimensional photograph nick crystal which has two-dimensional periodic refractive-index distribution.
[0002]
[Description of the Prior Art] The importance of spectral separation / multiplexing machine or a wavelength filter is increasing with progress of a wave-length-multiple-telecommunication system in recent years.
[0003] The optical branching insertion equipment for wave-length multiple telecommunication is also called an optical ADODOROPPU multiplexer, and takes out the signal of a certain channel from the multiplexed signal, or has the function added to a vacant part. As a general configuration, there are an array waveguide diffraction skeleton pattern, a fiber grating mold, etc. The inclination of the wave front which is a kind of diffraction grating with the structure where much optical waveguides from which die length differs were arranged, and is dependent on wavelength with the difference of the die length of this waveguide occurs, and an array waveguide diffraction grating will be separated spectrally and outputted from different waveguide for every wavelength, if wavelength multiplexing light is inputted (for example, the institute-of-telecommunications-engineers magazine p746 -749 (1999)). In a fiber grating mold, it becomes possible by carrying out Bragg reflection only of the signal of specific wavelength by the fiber grating to take out from a drop port or to input from an ADDO port.
[0004] However, in order to lessen bending loss, it will be necessary to enlarge radius of curvature considerably, and in the wavelength multi/demulitiplexer of the conventional array waveguide diffraction-grating mold, a component dimension will become very large.
[0005] Then, many ideas of forming the optical multiplexer/demultiplexer of a minima type using a photograph nick crystal are also proposed. For example, it is indicated by Applled Physics Letters, Vol.75, P3739-3741 (1999) (conventional technique 1), Physical Review Letters, Vol.80, P960-963 (1998) (conventional technique 2), etc.
[0006] A photograph nick crystal is a crystal which has periodic refractive-index distribution in the interior, and the new optical property by artificial period structure can be realized.
[0007] a photograph nick crystal -- **** -- the important description has existence of a photograph nick band gap. As the photograph nick crystal (following three-dimension photograph nick crystal) which has a three-dimension period, the perfect band gap to which propagation of light is forbidden to all directions can be formed. a light local by this -- shutting up -- control of ** and spontaneous emmision light, and a line -- formation of the waveguide by installation of **** is attained and implementation of a microscopic small optical circuit can be expected.
[0008] Although it is suggested to the conventional technique 1 that a micro optical separator can be formed by making into a branching configuration waveguide which introduced and formed the line defect in the three-dimension photograph nick crystal, it is not indicated about the concrete structure.

[0009] The analysis result of the splitter with which examination of a photograph nick crystal (following two-dimensional photograph nick crystal) which has two-dimensional period structure is briskly performed from production being comparatively easy, and used the waveguide of a branching configuration for the conventional technique 2 on the other hand is shown.
[0010] The refractive-index period structure of a two-dimensional photograph nick crystal arranges a cylinder hole a tetragonal lattice or in the shape of a triangular grid into a high refractive-index ingredient. Or it forms into a low refractive-index ingredient by arranging the cylinder of a high refractive-index ingredient in the shape of a tetragonal lattice. A photograph nick band gap is formed from such periodic structures, and propagation of light is controlled to the field intrinsic light. waveguide can be formed by introducing a linear defect into this periodic structure (Physical Review Letters, Vol.77, and p3787-3790 (1996) -- and (conventional technique 2)). [for example,]
[0011] The conventional technique 2 is the configuration where the cylinder which consists of a high refraction ingredient was arranged in the shape of a tetragonal lattice. However, although propagation of the light to field inboard is controllable by the band gap as mentioned above, since propagation of the light to the vertical direction is uncontrollable by periodic structure, it assumes that height is infinite and analysis of straight-line waveguide and 90-degree bending, and a branching configuration is performed.
[0012] However, since height cannot be made infinite in an actual device, it is necessary to shut up light in the height of finite.
[0013] On the other hand, when forming a cylinder hole in a high refractive-index ingredient, a high refractive-index ingredient is made into a slab configuration, a low refractive-index layer is prepared up and down, light is shut up by total reflection, and waveguide can be formed.
[0014] However, examination of the splitter in such structure, a multiplexing machine, etc. is not made. Moreover, the light spread to field inboard is drawn in the field direct direction, or the examination about 90-degree bending of leading the light from field direct to field inboard, and a branching configuration is not made, either.
[0015] Although the optical spectral separation and the multiplexing machine using the super prism by the self-cloning mold three-dimension crystal are also examined (for example, Applied Physics Letters, Vol74, P1212-1214 (1999), O plus E, the December issue, p1560-1565 (1999)), it was not combined with waveguide and examined by only the function as an independent device.
[0016] If it becomes possible from photograph nick crystal waveguide to input light into photograph nick crystal waveguide with wavelength selection nature or it outputs light with wavelength selection nature in a certain wavelength band, the optical circuit which has optical spectral separation very smaller than the usual component and a multiplexing function will become realizable. Moreover, if the light and the electromagnetic wave of two-dimensional photograph nick crystal waveguide can be drawn in the field direct direction, it can also consider as three-dimensional light and electromagnetic wave circuit.
[0017]
[Problem(s) to be Solved by the Invention] The purpose of this invention draws the light and the electromagnetic wave which spreads the inside of two-dimensional photograph nick crystal waveguide in the field direct direction, or it is the gestalt to input and it is offering the effective gestalt for forming light and electromagnetic wave waveguide, and light and an electromagnetic wave multi/demulitiplexer.
[0018]
[Means for Solving the Problem] The above-mentioned purpose is attained by the following configurations.
(1) In the slab currently formed from the ingredient with a refractive index higher than air It has the two-dimensional photograph nick crystal structure which arranged periodically the matter with a refractive index lower than this slab ingredient, and formed refractive-index distribution. The linear defect is formed in the periodic array of said photograph nick crystal, and this line defect has the photograph nick crystal waveguide which functions as waveguide, and adjoins said photograph nick crystal waveguide. In the light and the electromagnetic wave on which it has at least one punctiform defect which disturbs the periodic array of said photograph nick crystal, and this punctiform defect spreads the inside of waveguide Two-dimensional photograph nick crystal waveguide which

functions as the light and the electromagnetic wave ejection / an inlet which captures the light and the electromagnetic wave of specific wavelength, and emits this, or captures the light and the electromagnetic wave of the specific wavelength from the outside, and is introduced in said waveguide.
(2) Said light and electromagnetic wave ejection / inlet are the two-dimensional photograph nick crystal waveguide of the above (1) which emits / introduces the light and the electromagnetic wave of the direction which intersects perpendicularly with a slab side.
(3) Said punctiform defect is the two-dimensional photograph nick crystal waveguide of the above (1) from which the wavelength of the light and the electromagnetic wave emitted / introduced with the configuration differs.
(4) One two-dimensional photograph nick crystal waveguide of above-mentioned (1) - (3) with which a low refractive-index ingredient is filled up into the hole of the shape of a cylinder which the array of said low refractive-index matter formed in slab.
(5) One two-dimensional photograph nick crystal waveguide of above-mentioned (1) - (4) whose arrays of said low refractive-index matter are triangular lattices.
(6) Said punctiform defect is one two-dimensional photograph nick crystal waveguide of vertical above-mentioned [which has an unsymmetrical configuration] (1) - (5) to a slab side.
(7) One two-dimensional photograph nick crystal waveguide of above-mentioned (1) - (6) whose refractive indexes of said slab ingredient are 2.0 or more.
(8) Said slab ingredient is the two-dimensional photograph nick crystal waveguide of whether it is an inorganic material containing any one sort of In, Ga, aluminum, Sb, As, germanium, Si, P, N, and the O, or two sorts or more, and the above (7) which is an organic material.
(9) The matter with said low refractive index is one two-dimensional photograph nick crystal waveguide of above-mentioned (1) - (8) which is air (10). The above (1) Photograph nick crystal wavelength splitter which has the two-dimensional photograph nick crystal waveguide of - (9).
(11) The photograph nick crystal wavelength splitter of the above (10) with which the frequencies which have two or more punctiform defects, and this punctiform defect emits / captures differ, respectively.
(12) The above (10) or (11) photograph nick crystal wavelength splitters with which the optical fiber is arranged near the punctiform defect.
(13) The above (10) or (11) photograph nick crystal wavelength splitters with which the semiconductor device which has a photo-electric-conversion function is arranged near [said] the punctiform defect.
[0019]
[Embodiment of the Invention] The two-dimensional photograph nick crystal waveguide of this invention in the slab currently formed from the ingredient with a refractive index higher than air It has the two-dimensional photograph nick crystal structure which arranged periodically the matter with a refractive index lower than this slab ingredient, and formed refractive-index distribution. The linear defect is formed in the periodic array of said photograph nick crystal, and this line defect has the photograph nick crystal waveguide which functions as waveguide, and adjoins said photograph nick crystal waveguide. In the light and the electromagnetic wave on which it has at least one punctiform defect which disturbs the periodic array of said photograph nick crystal, and this punctiform defect spreads the inside of waveguide It functions as the light and the electromagnetic wave ejection / an inlet which captures the light and the electromagnetic wave of specific wavelength, and emits this, or captures the light and the electromagnetic wave of the specific wavelength from the outside, and is introduced in said waveguide.
[0020] The waveguide and the point defect in this invention can spread not only light but the electromagnetic wave which has a property near light, and can be outputted and inputted.
[0021] Thus, by forming a punctiform defect near the waveguide formed of the linear defect, the light and electromagnetic wave ejection / installation from a punctiform defect are attained, and light and electromagnetic wave ejection / inlet can be formed. This punctiform defect disturbs the two-dimensional photograph nick crystal structure which arranged periodically the matter with a refractive index lower than this slab ingredient in the slab currently formed from the ingredient with a refractive index higher than air, and formed refractive-index distribution in it.

[0022] Hereafter, the gestalt of operation of this invention is explained according to a drawing. As the 1st gestalt of this invention, a two-dimensional photograph nick crystal slab waveguide is adjoined, a point defect is prepared in drawing 1 , and the waveguide and the wavelength splitter which outputs the light and the electromagnetic wave of specific wavelength in the field direct direction are shown.
[0023] A photograph nick crystal and waveguide are described first. The photograph nick crystal used for this invention is a two-dimensional photograph nick crystal which has a band gap in field inboard according to two-dimensional refractive-index period distribution, and a crystal structure arranges the cylinder hole 16 in the shape of a triangular grid into the slab ingredient 11, as shown in drawing 1 .
[0024] Within a crystal, in field inboard, propagation is forbidden to incident light and an electromagnetic wave 13 (lambda 1, lambda 2, --lambdai, --) by the band gap, and it is shut up in the field direct direction by the total reflection by the up-and-down low refractive-index ingredient.
[0025] Here, as shown in drawing 1 , the linear defect 12 will be introduced into a photograph nick crystal by sampling in part the cylinder hole 16 arranged in the shape of a triangular grid to a line. Trapped mode **** in this line defect 12, and waveguide is formed.
[0026] Although an ingredient with a large refractive index is desirable and InGaAsP slab is used by this example as an ingredient of photograph nick crystal slab structure since it is necessary to shut up light and an electromagnetic wave in the vertical direction An organic material etc. can be used for inorganic materials, such as an ingredient which contains any one sort of GaAs, or In, Ga, aluminum, Sb, As, germanium, Si, P, N and O, or two sorts or more in others, and Si, especially an inorganic semiconductor material, and a pan.
[0027] The larger one as mentioned above is desirable, it is size, 2.0 or more are specifically more desirable than air, and with [the refractive index of the ingredient used as slab] 3.0 [or more], it is more desirable.
[0028] In addition, in the above-mentioned example, as shown, for example in drawing 3 , the cylinder hole 16 is arranged in the shape of triangular grid 16a, but as shown, for example in drawing 4 , the cylinder hole 16 can be arranged in the shape of tetragonal lattice 16b so that a photograph nick band gap may exist, and the photograph nick crystal which introduced the defect 12 into the line can also be used. in addition, some slab with which drawing 3 and 4 constitute a photograph nick crystal -- it is a top view.
[0029] Next, light and electromagnetic wave ejection / inlet is explained. As mentioned above, light and an electromagnetic wave can spread the inside of the defective waveguide of a two-dimensional photograph nick crystal. In straight-line waveguide, the wavelength region which can spread light and an electromagnetic wave by low loss is comparatively large. Therefore, the light and the electromagnetic wave of the wavelength band containing the wavelength of several channels can be made to spread in waveguide. On the other hand, while the light and the electromagnetic wave of specific wavelength will be captured here and resonating inside a defect if a point defect 14 is established near the waveguide as shown in drawing 1 , light and an electromagnetic wave 15 are emitted in the small vertical direction of the Q factor resulting from being a slab configuration.
[0030] Moreover, it can be made to function as the splitter which takes out the light and the electromagnetic wave of light and electromagnetic wave ejection / not only inlet but specific wavelength (lambdai), a multiplexing machine, or a filter by designing a point defect so that only the wavelength of the specific channel in a wavelength band may be captured. Moreover, according to this gestalt, the guided wave light within a field and an electromagnetic wave can be drawn in the field direct direction, and a fork road and a turn way can be formed in a very small field. Moreover, it is also possible to draw the light and the electromagnetic wave of the specific wavelength which carried out incidence in the field direct direction on the contrary at the waveguide within a field.
[0031] By setting up spacing of waveguide and ****** suitably, it is also possible to control the rate of the light and the electromagnetic wave of the specific wavelength captured and outputted. For this reason, light and an electromagnetic wave can be taken out at a predetermined rate, or the light and the electromagnetic wave circuit to branch can also be formed easily.
[0032] moreover, the thing for which vertical asymmetry is introduced into a defect although light and an electromagnetic wave are outputted in the vertical direction since vertical asymmetry is not

introduced into a defect especially in the gestalt of drawing 1 -- the upper and lower sides -- it is possible to also make light and an electromagnetic wave output only to either. The approach of making the configuration of a point defect 14 into the shape of a cone as an asymmetric introductory approach since cylindrical as shown, for example in drawing 5 , or changing the path of a point defect 14 by the upper and lower sides of slab 11 as shown in drawing 6 can be used. drawing 5 and 6 -- a part of point defect part -- it is a sectional view. [in addition,]

[0033] The gestalt which adjoined straight-line waveguide and formed two point defects 21 and 22 in drawing 2 as 2nd operation gestalt of this invention is shown. It is the gestalt which controlled the wavelength of the light and the electromagnetic waves 22 and 23 captured and outputted with the magnitude of each defect, and two waves (lambdai and lambdaj) of the band of the light and the electromagnetic wave (lambda 1, lambda 2, --lambdai, lambdaj --) inputted from each point defect can be outputted. The light and electromagnetic waves other than **** and the outputted wavelength guide the inside of straight-line waveguide. Moreover, although considered as the wavelength splitter of two channels in this example, multi-channel-izing more is also possible by increasing the number of defects.

[0034] Drawing 7 shows the concept of a multi/demulitiplexer which is the gestalt of operation of the 3rd of this invention. The light and the electromagnetic wave 31 of a certain wavelength band spread the inside of photograph nick crystal waveguide, is captured according to point defects 32-34, and is outputted in the field direct direction.

[0035] This light and electromagnetic wave are incorporated on the light and the electromagnetic wave fibers 35-37 arranged on the point defect, and it uses as a signal. As for light and an electromagnetic wave fiber, at this time, it is desirable to set the gap of extent which does not disturb the photograph nick crystal structure, and to be arranged on a point defect.

[0036] Or as shown in drawing 8 , it can also integrate with the semiconductor device 45-47 which has a photo-electric-conversion function, for example, photodiode arrays. Thereby, the light and the electromagnetic wave outputted in the field direct direction are convertible for a direct electrical signal within a very small area from point defects 42-44.

[0037] Below, the production approach of of the photograph nick crystal waveguide and the wavelength splitter of the operation gestalt of this invention is described.

[0038] First, as shown in drawing 9 , crystal growth of the InGaAsP layer 53 is carried out on the InP substrate 51 preferably [as the InP layer 52 and a high refractive-index slab ingredient] as a buffer layer. Crystal growth is preferably performed at 590-650 degrees C by the MOCVD method.

[0039] Then, as shown in drawing 10 , in order to form a triangular grid-like circular hole and the pattern of a point defect, the photoresist 54 for electron beam lithography is applied, as shown in drawing 11 , exposure and development are performed and patterning of the resist is carried out. The lattice constant of a photograph nick crystal is 0.5 micrometers also when the wavelength of an infrared region is assumed as propagation light and an electromagnetic wave. Below, extent and since it is very small, drawing by the electron ray is performed here.

[0040] Next, as shown in drawing 12 , a cylinder hole and a defect are formed in InGaAsP slab by RIE (Reactive Ion Etching) by using a resist as a mask. In RIE, it is H2. CH4 Mixed gas is used.

[0041] Next, as shown in drawing 13 , in order to make the slab upper and lower sides into the air space of a low refractive index after resist removal, InGaAsP slab is membrane-ized as shown in drawing 14 . Wet etching of this is carried out and it is performed so that only an InP layer may be etched alternatively.

[0042] Although InGaAsP was used as a high refractive-index slab ingredient in the above-mentioned example, since the refractive index of Si is high and processing by my chroma C NINGU is possible for it, it is a useful ingredient. The production approach at the time of using Si for below as a slab ingredient is described.

[0043] First, a SOI substrate is prepared as shown in drawing 15 . A SOI substrate is SiO2 on the Si substrate 61 used as the base. It is the substrate with which the laminating of the single crystal Si layer 63 is carried out through the layer 62. Moreover, it changes to this and is SiO2 on Si substrate. It is also possible to use the substrate into which the layer and Si layer were grown up. Next, as shown in drawing 16 , the photoresist 64 for electron beam lithography is applied to the SOI substrate 61, as shown in drawing 17 , exposure and development are performed and patterning of

the resist is carried out.
[0044] Then, as shown in drawing 18 , a cylinder hole and a defect are formed in the Si layer 63 by RIE by using a resist 64 as a mask. In RIE, it is SF6. Gas is used. Subsequently, as shown in drawing 19 , after removing a resist, as shown in drawing 20 , the oxide film layer under a photograph nick crystal is etched with HF water solution, and it membrane-izes.
[0045]
[Example] Hereafter, a property is shown about the example of this invention. First, it describes about a photograph nick crystal. 0.29a and thickness t of slab set the radius r of a hole to 0.6a, having used the lattice constant of a photograph nick crystal as a, as photograph nick crystal slab was constituted from InGaAsP, for example, it was shown in drawing 21 R> 1.
[0046] On the other hand, about the case where a line defect and a point defect are established, it analyzed by the time domain finite difference method (Finite Difference Time Domain:FDTD), and the result shown below was obtained. In addition, the method of a maxwell is the approach of solving directly the rotation equation for which it depends on time amount among equations, and when a time domain finite difference method is explained briefly, it is as follows.
[0047] In an isotropic medium, an equation is written as follows like the method of a maxwell.
[0048]
[Equation 1]

$$\nabla \times E = -\mu \frac{\partial H}{\partial t}$$

$$\nabla \times H = +\varepsilon \frac{\partial E}{\partial t}$$

[0049] Here, mu is [a dielectric constant and C of permeability and E] conductivity. If these formulas are difference-ized, the following six formulas will be obtained.
[0050]
[Equation 2]

$$H_x^{n+\frac{1}{2}}\left(i, j+\frac{1}{2}, k+\frac{1}{2}\right) = H_x^{n-\frac{1}{2}}\left(i, j+\frac{1}{2}, k+\frac{1}{2}\right) + \frac{\Delta t}{\mu\left(i, j+\frac{1}{2}, k+\frac{1}{2}\right)}\left[\frac{E_y^n\left(i, j+\frac{1}{2}, k+1\right) - E_y^n\left(i, j+\frac{1}{2}, k\right)}{\Delta z} + \frac{E_z^n\left(i, j, k+\frac{1}{2}\right) - E_z^n\left(i, j+1, k+\frac{1}{2}\right)}{\Delta y}\right] \quad (1)$$

$$H_y^{n+\frac{1}{2}}\left(i+\frac{1}{2}, j, k+\frac{1}{2}\right) = H_y^{n-\frac{1}{2}}\left(i+\frac{1}{2}, j, k+\frac{1}{2}\right) + \frac{\Delta t}{\mu\left(i+\frac{1}{2}, j, k+\frac{1}{2}\right)}\left[\frac{E_z^n\left(i+1, j, k+\frac{1}{2}\right) - E_z^n\left(i, j, k+\frac{1}{2}\right)}{\Delta x} + \frac{E_x^n\left(i+\frac{1}{2}, j, k\right) - E_x^n\left(i+\frac{1}{2}, j, k+1\right)}{\Delta z}\right] \quad (2)$$

[0051]
[Equation 3]

$$H_z^{n+\frac{1}{2}}\left(i+\frac{1}{2},j+\frac{1}{2},k\right) = H_z^{n-\frac{1}{2}}\left(i+\frac{1}{2},j+\frac{1}{2},k\right) + \frac{\Delta t}{\mu\left(i+\frac{1}{2},j+\frac{1}{2},k\right)}\left[\frac{E_x^n\left(i+\frac{1}{2},j+1,k\right)-E_x^n\left(i+\frac{1}{2},j,k\right)}{\Delta y} + \frac{E_y^n\left(i,j+\frac{1}{2},k\right)-E_y^n\left(i+1,j+\frac{1}{2},k\right)}{\Delta x}\right] \quad (3)$$

$$E_x^{n+1}\left(i+\frac{1}{2},j,k\right) = E_x^n\left(i+\frac{1}{2},j,k\right) + \frac{\Delta t}{\varepsilon\left(i+\frac{1}{2},j,k\right)}\left[\frac{H_z^{n+\frac{1}{2}}\left(i+\frac{1}{2},j+\frac{1}{2},k\right)-H_z^{n+\frac{1}{2}}\left(i+\frac{1}{2},j-\frac{1}{2},k\right)}{\Delta y} + \frac{H_y^{n+\frac{1}{2}}\left(i+\frac{1}{2},j,k-\frac{1}{2}\right)-H_y^{n+\frac{1}{2}}\left(i+\frac{1}{2},j,k+\frac{1}{2}\right)}{\Delta z}\right] \quad (4)$$

[0052]
[Equation 4]

$$E_x^{n+1}\left(i,j+\frac{1}{2},k\right)$$

$$= E_y^n\left(i,j+\frac{1}{2},k\right)+\frac{\Delta t}{\varepsilon\left(i,j+\frac{1}{2},k\right)}\left[\frac{H_z^{n+\frac{1}{2}}\left(i,j+\frac{1}{2},k+\frac{1}{2}\right)-H_z^{n+\frac{1}{2}}\left(i,j+\frac{1}{2},k-\frac{1}{2}\right)}{\Delta z}+\frac{H_z^{n+\frac{1}{2}}\left(i-\frac{1}{2},j+\frac{1}{2},k\right)-H_z^{n+\frac{1}{2}}\left(i+\frac{1}{2},j+\frac{1}{2},k\right)}{\Delta z}\right] \quad (5$$

$$E_z^{n+1}\left(i,j,k+\frac{1}{2}\right)$$

$$= E_z^n\left(i,j,k+\frac{1}{2}\right)+\frac{\Delta t}{\varepsilon\left(i,j,k+\frac{1}{2}\right)}\left[\frac{H_z^{n+\frac{1}{2}}\left(i+\frac{1}{2},j,k+\frac{1}{2}\right)-H_y^{n+\frac{1}{2}}\left(i-\frac{1}{2},j,k+\frac{1}{2}\right)}{\Delta x}+\frac{H_y^{n+\frac{1}{2}}\left(i,j-\frac{1}{2},k+\frac{1}{2}\right)-H_x^{n+\frac{1}{2}}\left(i,j+\frac{1}{2},k+\frac{1}{2}\right)}{\Delta y}\right] \quad (6)$$

[0053] Six upper formulas are used and the situation of propagation of the light and the electromagnetic wave in photograph nick crystal slab can be analyzed. The frequency spectrum is called for by observing and carrying out the Fourier transform of the electric field on ****** and a defect.

[0054] First, it describes about the straight-line waveguide except a cylinder hole by one period. As for light and an electromagnetic wave, normalized radiam frequency f can spread the inside of waveguide without a loss in the range of 0.27-0.28 [c/a]. It is decided that the wavelength of light and an electromagnetic wave [an electromagnetic wave] to make it spreading a lattice constant a fulfills this condition. this example -- the wavelength of propagation light and an electromagnetic wave -- 1.55 micrometers f= 0.275 [c/a] which it sets up and is the core of 0.27-0.28 [c/a] -- 1.55 micrometers ** -- carrying out -- a -- 0.275xl.55 micrometer from -- asking -- 0.42625 micrometers ** -- it carried out.

[0055] The frequency of light and an electromagnetic wave and the strong relation which are emitted in the field direct direction from the point defect which adjoined waveguide and was prepared in drawing 22 are shown. In addition, the point defect has changed and established the radius of one cylinder hole, and the radius was set to 0.56. From drawing, it is checked that the light and the electromagnetic wave of normalized radiam frequency f= 0.273 [c/a] emanate in the vertical direction. Moreover, Q value is about 500.

[0056] The frequency and reinforcement of synchrotron orbital radiation and an electromagnetic wave from each point defect in the gestalt shown in drawing 23 at drawing 2 , i.e., the gestalt which established the point defect of magnitude which adjoins and is different at straight-line waveguide, are shown. The radius used the point defect in this case as the cylinder hole of 0.56a and 0.58a, respectively. It is checked that the light and the electromagnetic wave of f= 0.2729 [c/a] and f= 0.2769 [c/a] are emitted for a frequency, respectively. Moreover, each Q value of a defect is about 500.

[0057] It was checked that the waveguide formed in the two-dimensional photograph nick crystal by installation of a point defect and a line defect has the light and the electromagnetic wave ejection / introductory function from a point defect, and a function as a truing force type wavelength spectral separation / multiplexing machine from these results.

[0058]

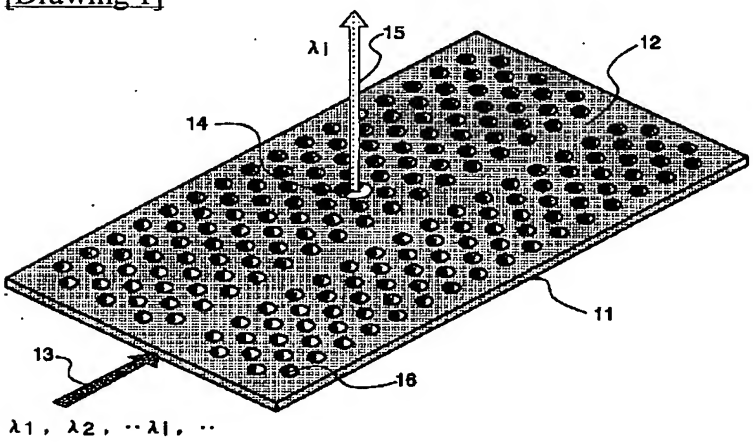
[Effect of the Invention] As mentioned above, in spite of being the two-dimensional photograph nick crystal structure, it is possible to output and input light and an electromagnetic wave in the field direct direction, and further, since the light and the electromagnetic wave of specific wavelength can be separated spectrally, outputted and inputted from a point defect, a micro wavelength splitter is realizable in the wavelength splitter which established and formed the point defect near the two-dimensional photograph nick crystal waveguide like this invention. This enables implementation of an again comparatively easy three-dimensional micro light and electromagnetic wave circuit.

* NOTICES *

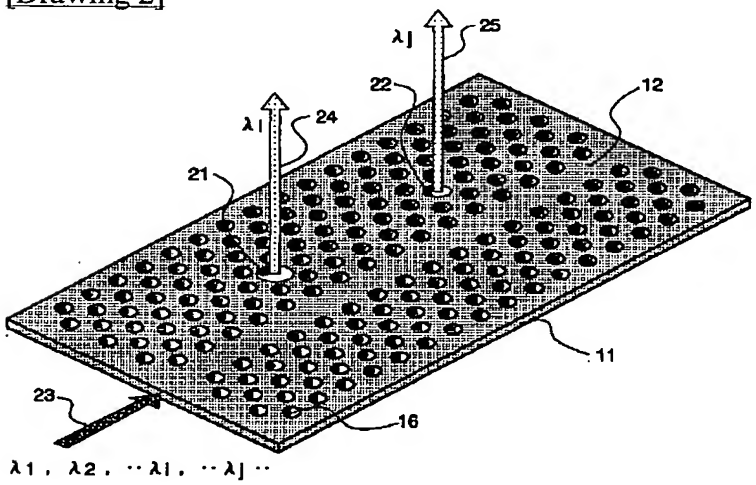
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

[Drawing 1]



[Drawing 2]



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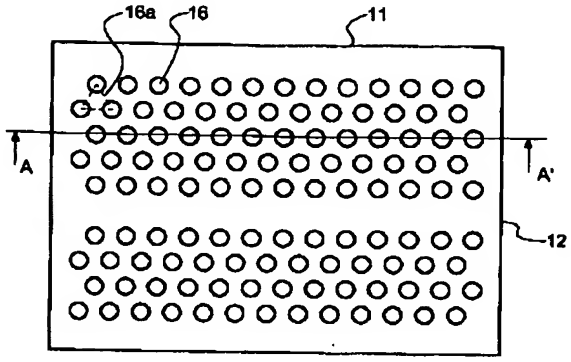

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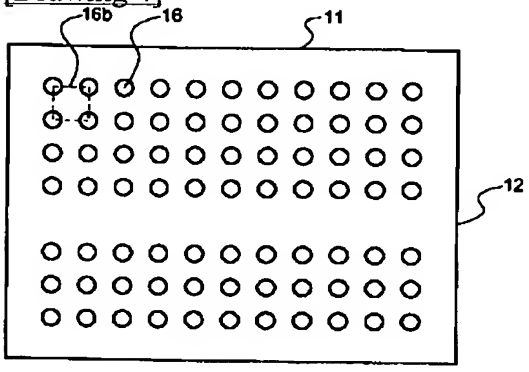
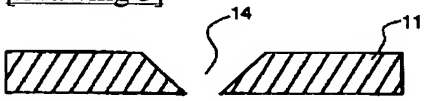


[Drawing 5]



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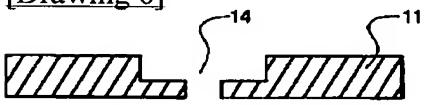

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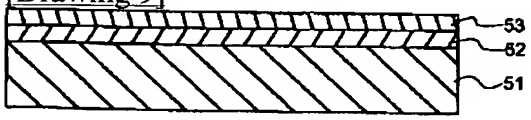

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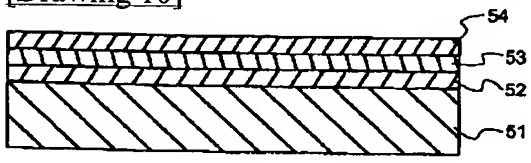

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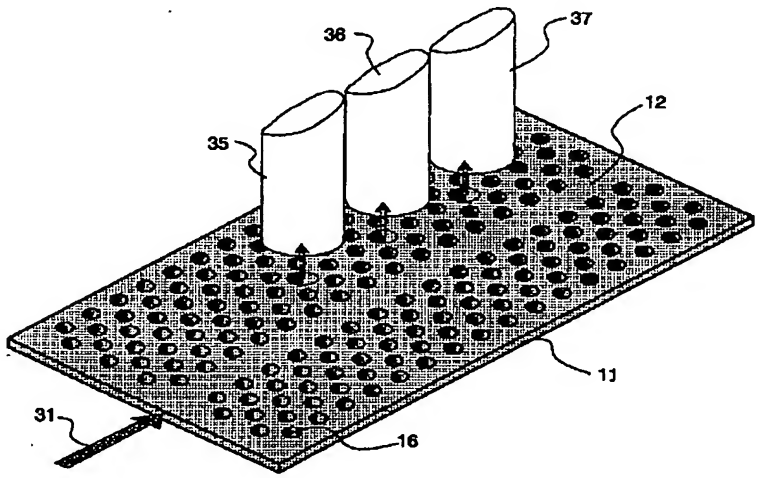

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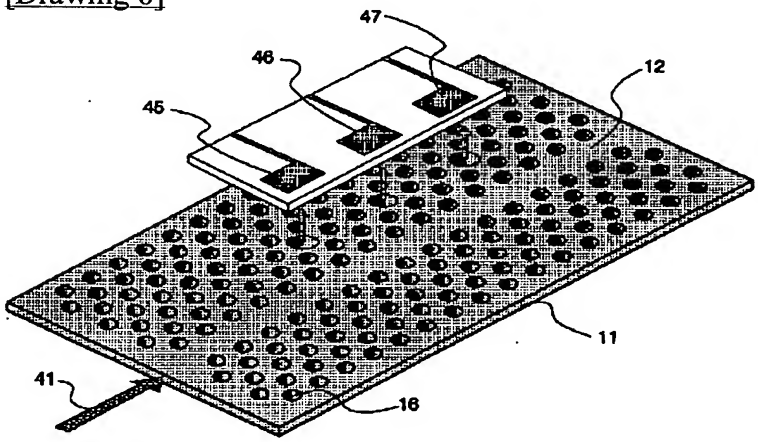

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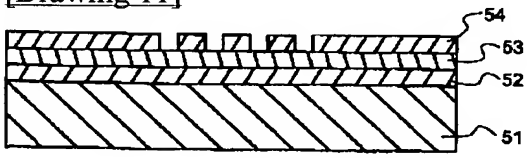

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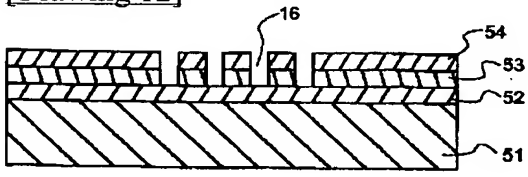

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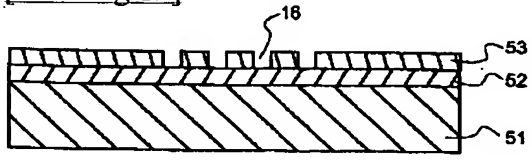

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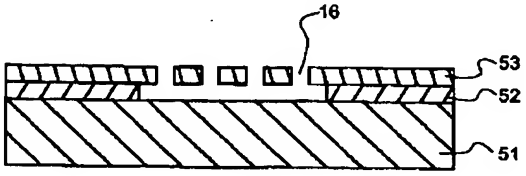

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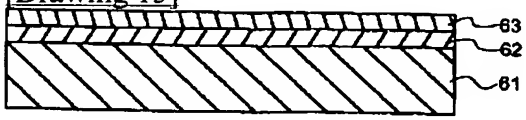

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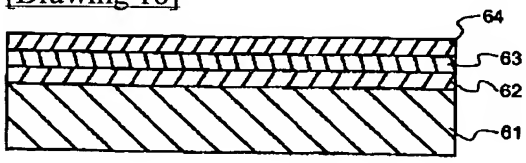

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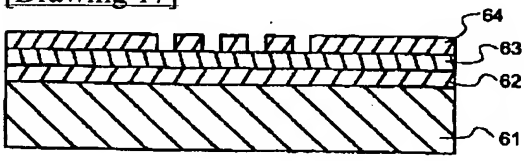

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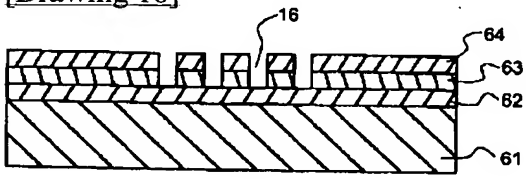
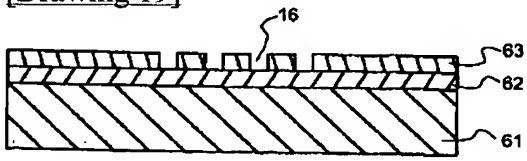
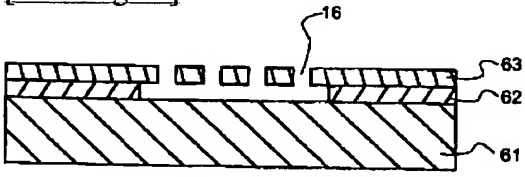


[Drawing 19]



[Drawing 20]



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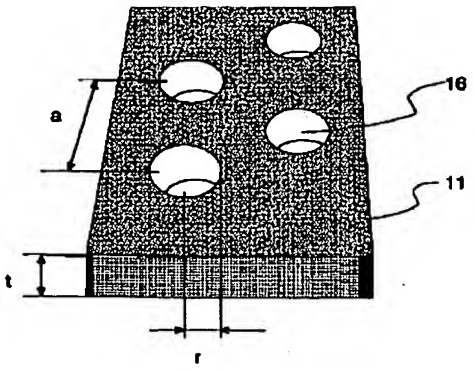

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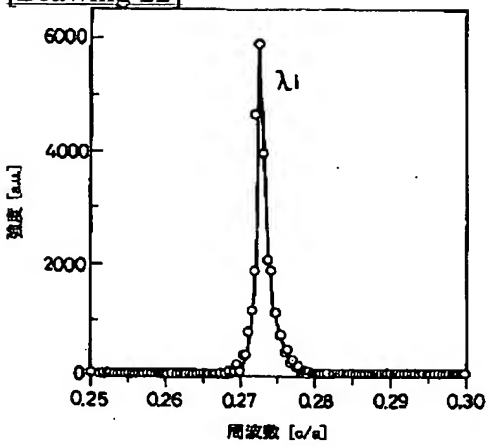
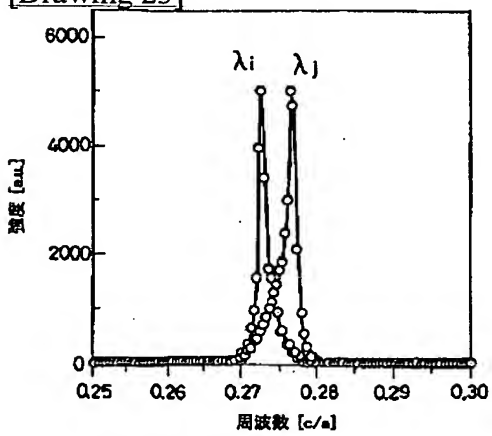


[Drawing 23]



[Translation done.]